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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report addresses the long-term evaluation of the Mayport heat recovery incinerator program. Operational data was collected from 29 Sep 1980 to 28 Sep 1981 and then analyzed for reliability, availability, maintainability, thermal efficiency, and operating cost.

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I. INTRODUCTION

The Resource, Conservation and Recovery Act (RCRA) of 1976 mandates the use of fuel derived from recovered-material to the maximum extent practicable in Federally owned fossil fuel-fired energy systems. The Naval Station (NS) Mayport, Heat Recovery Incinerator (HRI) installation is one of two facilities installed to recover energy from solid waste generated on base. The other is located at Naval Air Station (NAS), Jacksonville. By the incineration of waste materials, NS Mayport is intended to reduce landfill problems, and generate steam to be used by Naval ships at port as well as shore activities.

A. Purpose. The purpose of this task is to evaluate the performance of the HRI; determine Reliability, Availability, and Maintainability (RAM) parameters, long-term cost-effectiveness, and overall thermal efficiency results will be used to develop Navy criteria for the optimum plant design in the 50 ton per day (TPD) range.

B. Scope. This task involved condensing operational data logged for a full year (29 September 80 to 28 September 81) into 52 sets of weekly data; hereafter referenced as fiscal year 81 (FY-81). This data was then analyzed and used to compute RAM parameters, thermal efficiency and operating cost of the HRI using the guidance of Naval Civil Engineering Laboratory (NCEL) Memorandum M-63-80-11.

To condense the data and perform the analysis and subsequent calculations a thorough understanding of the functional operation of the HRI was required. These efforts were supported by the following documents:

(1) "Memorandum of procedure for FY-81 evaluation of the NS Mayport HRI for Reliability and Maintainability", by Dr. Suresh C. Garg, Sept. 1980.

(2) "Test and Evaluation of the Heat Recovery Incinerator System at Naval Station, Mayport, Florida", an investigation conducted by Systech Corporation, May 1981.

(3) "Operation and Maintenance Manual: Refuse Incinerator Mayport Naval Station."

In addition, during a site visitation numerous conversations with HRI contractor personnel and NCEL HRI project personnel provided additional information.

II. SUMMARY

The following parameters are the result of the long-term evaluation of the heat recovery incinerator at Navy Station Mayport, Florida, for the fiscal year 1981.

A. Reliability, Availability, Maintainability

Function	R*	A_o	MTBF** (hrs)	MTBMA (hrs)	# of Failures	# of Maint. Actions
Incinerate and produce steam with solid waste	0.3858	0.4890	126	89	27	11
Incinerate solid waste only	0.4768	0.5414	162	110	21	10
Produce steam without solid waste	0.7026	0.5606	340	261	10	3

*Based on 120 hour mission
**Based on an operating time of 3400 hours

B. Overall HRI System Parameters

Thermal Efficiency (TE) = 0.415

Specific Total Manhours (STM) = 0.497 manhours/10^6 Btu

Average Cost of Steam (ACS) = \$9.13/10^6 Btu

Percentage Landfill Reduction (PLR) = 70%

C. Breakdown of Time Categories

T_a = 3400 hours (Time spent operating the HRI)

T_b = 747 hours (Time spent in active preventive maintenance)

T_c = 821 hours (Time spent in active corrective maintenance)

T_d = 1784 hours (Time the HRI was idle and operational)

T_e = 1985 hours (Time the HRI was idle and not operational)

III. TECHNICAL DISCUSSION

This section provides a summary of the data collected and the resulting RAM, efficiency and cost parameters for the NS Mayport HRI installation during FY-81.

Table 1 provides the totals of the various times, fuel, water and waste consumed and the steam produced during the test period. All the parameters represent the information for 364 calendar days (i.e. 8736 hours) and 260 operating days (i.e. 6240 hours). Of the total possible hours (8736), the HRI installation spent 3400 hours operating, 1568 hours in maintenance (both routine and corrective), and 3769 hours of idle time (operational and non-operational combined). This idle time is made up mostly of weekends and holidays when the HRI did not run. Under normal operating conditions, the HRI was idle from midnight Friday night until midnight Sunday night with approximately 6 hours (calendar time) of that time spent in scheduled maintenance. Appendix A provides the detailed weekly values of this data.

Table 2 provides the description of the maintenance actions that occurred on the HRI. A maintenance action includes any task that requires the replacement of a failed component, adjustment or unjamming of an item, and any other

Table 1. NS Mayport HRI Summary Data.

	FY-81 Data Base	Value
	TIME CATEGORY	
1.	Calendar Time in Operation (incinerator, boiler)	3,400 hours
2.	Calendar Time in Operation (overhead crane, ash conveyor and feed ram)	3,198 hours
3.	Man-hours spent in Operation	10,686 hours
4.	Calendar time in Corrective Maintenance	197 (821) hours
5.	Man-hours spent in Corrective Maintenance	606 (1,228) hours[1]
6.	Calendar time in Routine Maintenance	747 hours
7.	Man-hours spent in Routine Maintenance	780 (2,587) hours[2]
8.	Time HRI idle, but operational	1,784 hours
9.	Time HRI idle, not operational	1,985 hours
	FUEL, WATER, WASTE, STEAM	
10.	Fuel waste oil consumed	188,851 gallons
11.	Fuel oil consumed	981 gallons
12.	Makeup water consumed	3,778,500 gallons
13.	Blowdown	905,879 gallons
14.	Solid waste incinerated	3,576 tons
15.	Solid waste rejected (hand-picked)	174 tons
16.	Wet ash	947 tons
17.	Fly ash	14 tons
18.	Steam produced	24,584,199 pounds

1 Approximately 622 man-hours were spent on installation problems requiring corrective maintenance (i.e., problems due to inadequate design rather than faulty equipment).

2 Approximately 1,807 man-hours were spent on non-required preventive maintenance (i.e., preventive maintenance that was performed in addition to scheduled maintenance) and 780 hours spent on scheduled maintenance.

action necessary to restore the HRI to full operation. There were 38 maintenance actions that included 27 failures. The major repetitive maintenance actions included the feed ram sticking, crane radio electronics failing, and ash conveyor problems (chain off sprocket and broken shear pins). Appendix B provides a detailed listing by functional area for each of the maintenance actions.

Table 2. NS Mayport HRI Maintenance Action Summary Data.

	Equipment	Failures	Other
1.	Front-end loader, overhead crane, hopper, feed ram.	8	6
2.	Incinerator	5	2
3.	Ash conveyor	8	2
4.	Boiler, deaerator, ID fan	6	1
	TOTALS	27	11
	Function		
5.	Incinerate and produce steam with solid waste (requires 1-4 above)	27	11
6.	Incinerate solid waste (requires 1-3 above)	21	10
7.	Produce steam without solid waste (requires 2, and 4 above)	10 *	3

*Stoker failure removed from 2 above for this function.

Table 3 provides the RAM, thermal efficiency and cost parameters for the period of time covered by this report.

The demonstrated Mean-Time-Between-Failures (MTBF) for the entire HRI installation was 126 hours. This means that on the average one would expect to operate for 126 hours between consecutive failure induced shutdowns. By

Table 3. NAS Mayport HRI RAM, Thermal Efficiency, Cost.

	Parameter	Value
1.	Mean-Time-Between-Failures (MTBF)	
	a. Incinerate and produce steam with solid waste ($MTBF_1$)	126 hours
	b. Incinerate solid waste ($MTBF_2$)	162 hours
	c. Produce steam without solid waste ($MTBF_3$)	340 hours
2.	Mean-Time-Between-Maintenance Actions (MTBMA) (includes failures and other maintenance actions (i.e. adjustments)	
	a. Incinerate and produce steam with solid waste ($MTBMA_1$)	89 hours
	b. Incinerate solid waste ($MTBMA_2$)	110 hours
	c. Produce steam without solid waste ($MTBMA_3$)	261 hours
3.	Reliability	
	a. Incinerate and produce steam with solid waste (R_1)	0.3858
	b. Incinerate solid waste (R_2)	0.4768
	c. Produce steam without solid waste (R_3)	0.7026
4.	Operational Availability (A_o)	
	a. Incinerate and produce steam with solid waste (A_{o1})	0.4890
	b. Incinerate solid waste (A_{o2})	0.5414
	c. Produce steam without solid waste (A_{o3})	0.5606
5.	Mean-Time-to-Repair (MTTR)	8 (30) hours[1]
6.	Preventive Maintenance Ratio (PMR)	0.23 (0.76)[2]
7.	Corrective Maintenance Ratio (CMR)	0.18 (0.36)[3]
8.	Maintainability Index (MI)	0.41 (1.12)
9.	Thermal Efficiency (TE)	0.415
10.	Specific Operating Man-hours (SOM)	0.366[4]
11.	Specific Repair and Maintenance (SRM) Man-hours	0.31[4]
12.	Specific Total Man-hours (STM)	0.497[4]
13.	Specific Repair and Maintenance Cost (SRC)	\$0.88[5]
14.	Specific Consumable Cost (SCC)	\$3.28[5]
15.	Average Cost of Steam (ACS)	\$9.13[5]

1 More representative value of MTTR is 8 hours. See discussion.
2 More representative value of PMR is 0.23. See discussion.
3 More representative value of CMR is 0.18. See discussion.
4 Labor hours per 10^6 Btus
5 Dollars per 10^6 Btus

evaluating the times to failure data and applying statistical analysis to these times a 90% confidence level was established. The 90% confidence level for the observed data was 97 hours. This means that there is a 90% confidence that the next set of observed data (i.e. the mean) will be at least 97 hours. Section IV provides a detailed discussion of this statistical manipulation.

The demonstrated Mean-Time-Between Maintenance Actions (MTBMA) for the entire HRI installation was 89 hours. This means that on the average one would expect to operate 89 hours and then require a maintenance action (i.e. to replace a failed item or unjam an item). Maintenance actions include all corrective actions whether or not a failure occurred.

The demonstrated Reliability (R) for the entire HRI installation was 0.3858. This means that there is a 0.3858 probability that the HRI will operate trouble-free for 120 consecutive hours (5 days at 24 hours) during a normal operation cycle.

The demonstrated operational availability (A_o) for the entire HRI installation was 0.4890. This means that there is a 0.4890 probability that the HRI will be capable of performing all of its function when called upon at any random point in time.

There were 27 repairs associated with the 27 failures of the HRI that were used in the Mean-Time-To-Repair (MTTR) computations and that accounted for 1228 manhours (821 calendar hours). Three repairs (622 manhours) were more associated with design changes (i.e., two relief stacks and one drain piping) and were removed from the following analysis. In addition, there was corrective maintenance time associated with the remaining 24 repairs that were not directly spent on the failures. These times were also removed and the results provide 197 hours of calendar time spent on corrective maintenance. This produced an HRI MTTR of 8.2 hours.

This indicates that on the average, a minimum of 8 hours (a complete shift) is required to restore a failed condition. A brief discussion of each subsystems maintenance problems follows.

1. Incineration Subsystem. MTTR = 12.1 hours (four failures)

The four incineration subsystem repair times ranged from 6 to 16 hours. Two ID fan damper motor failures required 16 and 12 hours of active repair time. One of these was determined to have been caused by a power surge. Technical assistance was required from Leeds and Northrup for both failures. Repair costs for these two failures totaled over $2700 which represents nearly 30 percent of the total HRI repair parts costs.

2. Processing Subsystem. MTTR = 10.8 hours (eight failures)

This subsystem consists of the front-end loader, overhead crane, hopper, and incinerator ram feed. The eight subsystem failures were divided evenly between the overhead crane and the feed ram hydraulics. Cumulative active repair times were 48.5 and 37.9 hours respectively. The most serious maintenance burden involved repairing worn trolley wheels and a bad receiver board on the overhead crane. $1300 dollars and 28 active repair hours were spent to repair this problem.

3. Boiler and Ash Removal Subsystems. MTTR = 5.5 and 5.0 (four and eight failures, respectively).

Relative to the other two subsystems both of these subsystems represent minor maintenance burdens. The most frequent failure involved broken shear pins which protect ash conveyor drive components.

The Preventive Maintenance Ratio (PMR) of 0.76 appears extremely high. This means that for every twenty-four hours of operation, eighteen man-hours are required for routine (preventive) maintenance. The PMR ratio is determined by dividing the man-hours spent on preventive maintenance by the total

operating time. During corrective maintenance and HRI idle periods, considerable amounts of preventive (i.e. routine) maintenance were performed, but not necessarily required. When the HRI was not operating, the personnel on shift would perform routine maintenance since they were on duty. It is estimated and substantiated by on-site personnel that only about 15 hours maximum per week were spent on required routine maintenance (i.e. blowdown, cleanout of second combustion chamber and fire tubes). This would translate into 780 hours for one year. The revised PMR would then be 0.23. This appears to be a more realistic value.

The Corrective Maintenance Ratio (CMR) was 0.36. This means that for every twenty-four hours of operation, over eight man-hours are required for corrective maintenance. The CMR ratio is determined by dividing the man-hours spent on corrective maintenance by the total operating time. If the two corrective maintenance tasks mentioned during the discussion on MTTR (modification to the relief stack and changing drain piping) were deleted, the revised CMR would be 0.18.

The above rationale also holds true for the Maintainability Index (MI). The MI for the HRI installation was 1.12. This means that for every twenty-four hours of operation, twenty-seven man-hours are spent on corrective and preventive maintenance. By using the revised PMR and CMR, the revised MI would be 0.41. This means that for every twenty-four hours of operation, that ten man-hours of corrective and preventive maintenance time will be required.

The overall Thermal Efficiency for the HRI was 0.415. This means that for every BTU entering the HRI in the form of solid waste kilowatt hours, and fuel oil; a little less than half a BTU was released in the form of steam. Thermal Efficiency is determined by dividing the BTU's of steam produced by the total number of BTU supplied to the HRI.

In calculating the average cost of steam (equation 38), it is indicated that to produce 1,000,000 Btus of heat over FY81, it cost $9.13. This equation takes into account the cost of repair and replacement parts, the cost of consumable items (i.e., water treatment chemicals, fuel, etc.) and labor costs. Only direct labor costs were considered and were based on an estimate of $10.00 per hour.

Section III provides the computations of the parameters listed in table 3.

The long-term solid waste disposal efficiency parameters are shown in table 4. The data used was extracted from Appendix A and the computations are contained in Technical Discussion Section D.

Table 4. Long-Term Solid Waste Disposal Efficiency

1.	Processing rate of the HRI facility in tons per hour.	1.05
2.	Efficiency of steam production in pounds of steam per pound of solid waste	3.44
3.	Efficiency of solid waste weight reduction through incineration	0.735
4.	Efficiency in reducing landfill (by weight) for solid waste accepted at HRI	0.697

IV. DATA ANALYSIS

The calculations of the various parameters contained in table 3 of the Summary used the equations listed in reference 1. Additional manipulation of the data was required to provide the desired RAM, thermal efficiency and cost parameters. All numbers used in RAM calculations were obtained directly from the appendices, numbers used in TE calculations were obtained from reference

(2) and thermodynamics tables, and the numbers used in the cost factor calculations were obtained from documents supplied by the contractor and affiliated public works department. The following provide the rationale and computation of these parameters.

A. RAM

Three separate values of each reliability and availability parameter were developed to represent the three primary missions of the HRI. The following equations were used to compute the RAM parameters based upon data extracted from Appendices A and B.

RAM Equations	FY-81 Data Base	
1. $MTBF = \frac{t_a}{N_f}$	$MTBF_1 = \frac{3399.46}{27} = 126$ hours	(1)
where	$MTBF_2 = \frac{3399.46}{21} = 162$ hours	(2)
t_a = operating time for specific mission (hours)	$MTBF_3 = \frac{3399.46}{10} = 340$ hours	(3)
N_f = number of failures - See Table 2		
2. $MTBA = \frac{t_a}{N_{ma}}$	$MTBMA_1 = \frac{3399.46}{38} = 89$ hours	(4)
where	$MTBMA_2 = \frac{3399.46}{31} = 110$ hours	(5)
t_a = operating time for specific mission (hours)	$MTBMA_3 = \frac{3399.46}{13} = 262$ hours	(6)
N_{ma} = number of maintenance actions - See Table 2		

RAM Equations	FY-81 Data Base	
3. $R = e^{-\lambda t}$	$R_1 = e^{-120/126} = 0.3858$	(7)
where	$R_2 = e^{-120/162} = 0.4768$	(8)
e = naperian base (2.718)	$R_3 = e^{-120/340} = 0.7026$	(9)
λ= failure rate for specific mission. = 1/MTBF		
t_m = mission time (120 hours)		
4. $A_o = \dfrac{t_a}{t_a + t_b + t_c + t_e}$	$A_{o1} = \dfrac{3399.46}{3399.46+747.14+820.68+1984.95}$ $= 0.4890$	(10)
where	$A_{o2} = \dfrac{3198.46}{3198.46+747.14+721.37+1240.26}$ $= 0.5414$	(11)
t_a = operating time for specific mission (hours) t_b = time spent in routine maintenance (hours)	$A_{o3} = \dfrac{3399.46}{3399.46+747.14+557.68+1359.88}$ $= 0.5606$	(12)
t_c = corrective maintenance for specific mission t_e = idle, non-operational time for specific mission		
5. $MTTR = \dfrac{t_c}{N_r}$	$MTTR = \dfrac{821}{27} = 8.2$ hours	(13)
where		
t_c = total active corrective maintenance time of repairs - See Appendix A Table 1		
N_r = number of repairs		
6. $PMR = \dfrac{Mt_b}{t_a}$	$PMR = \dfrac{2587}{3400} = 0.76$	(14)
where		
Mt_b = man-hours spent on routine maintenance		
t_a = total operating time		

RAM Equations (Continued)	FY-81 Data Base	
7. $CMR = \frac{Mt_c}{t_a}$	$CMR = \frac{1228}{3400} = 0.36$	(15)

where

Mt_c = man-hours spent on corrective maintenance

t_a = total operating time

8. $MI = \frac{Mt_b + Mt_c}{t_a}$	$MI = \frac{3815}{3400} = 1.12$	(16)

where

t_a = total operating hours

Mt_b = man-hours spent on routine maintenance

Mt_c = man-hours spent on corrective maintenance

B. Long-term Thermal Efficiency

The equation for long-term thermal efficiency was taken directly from reference 1 and solved using the information from Appendix A.

$$TE = \frac{M_{15} \times h_s}{H_{hri}} = \frac{2.918 \times 10^{10} \text{ Btus}}{7.04 \times 10^{10} \text{ Btus}} = 0.415 \qquad (17)$$

where

TE = Thermal efficiency

M_{15} = Steam generated, pounds

h_s = Heat of steam, Btu/pounds

H_{hri} = Btus supplied to HRI

H_{hri} is determined by the addition of the heat in Btus derived from the various energy sources supplied directly to the HRI or consumed indirectly.

Equations 18-24 provide for the individual computation of heat from the various energy sources. In simplified form,

$$H_{hri} = H_{sw} + H_{vo} + H_{wo} + H_f + E_t + H_w \tag{18}$$

where

H_{hri} = Btus supplied to HRI

H_{sw} = Heat in Btus derived from solid waste and supplied to HRI

H_{vo} = Heat in Btus derived from virgin oil and supplied to HRI

H_{wo} = Heat in Btus derived from waste oil and supplied to HRI

H_f = Heat in Btus from fuel oil supplied to front-end loader

E_t = Electrical power in Btus supplied to the HRI

H_w = Thermal energy in Btus of the makeup water supplied to the HRI

Efficiency Equations

1. Heat derived from solid waste.

$$H_{sw} = (h_{sw})(M_{12}) = (5137 \text{ Btu/pound})(2000 \text{ pounds/ton})(3576.28 \text{ tons}) = 3.672 \times 10^{10} \text{Btu} \tag{19}$$

where

H_{sw} = Heat in Btus derived from solid waste and supplied to HRI.

h_{sw} = Heating value of solid waste in Btu/pound

M_{12} = Solid waste supplied to HRI in pounds

2. Heat derived from virgin oil.

$$H_{vo} = (h_{vo})(M_{20}) = (1 \text{ barrel/42 gallons})(5.83 \times 10^6 \text{Btu/barrel})(981 \text{ gallons}) = 1.362 \times 10^8 \text{ Btu} \tag{20}$$

Efficiency Equations (Continued)

where

H_{vo} = Heat in Btus derived from virgin oil and supplied to HRI

h_{vo} = Heating value of virgin oil in Btu/pound

M_{20} = Virgin oil supplied to HRI in pounds

3. Heat derived from waste oil.

$$H_{wo} = (h_{wo})(M_{21}) = (19{,}673 \text{ Btu/pound})(6.86 \text{ pound/gallon})(188{,}851 \text{ gallons})$$

$$= 2.549 \times 10^{10} \text{ Btu} \tag{21}$$

where

H_{wo} = Heat in Btus derived from waste oil and supplied to HRI

h_{wo} = Heating value of waste oil in Btu/pound

M_{21} = Waste oil supplied to HRI in pounds

4. Heat derived from front-end loader.

$$*H_f = (h_f)(M_{22}) = 0.021 \times 10^{10} \text{ Btu} \tag{22}$$

where

h_f = Heating value from fuel oil in Btu/pound

M_{22} = Fuel oil supplied to front-end loader in pounds

*Estimated value based on information given by plant personnel.

5. Energy equivalent of electrical power supplied to the HRI.

$$E_t = (e_t)\ (T_{kwh}) = (1.964 \times 10^6 \text{ Btu/hour})(3400 \text{ hours}) \tag{23}$$

$$= 0.6852 \times 10^{10} \text{ Btu}$$

where

E_t = Electrical power in Btus supplied to the HRI

e_t = Conversion factor in Btus/KwH

T_{kwh} = Total KwH (kilowatt hours) supplied to the HRI

Efficiency Equations (Continued)

6. Thermal energy of makeup water supplied to the HRI.

$$H_w = (h_w)(M_{17}) = (48 \text{ Btu/pound})(8.3 \text{ pounds/gal})(3{,}778{,}500 \text{ gals}) \quad (24)$$

$$= 0.1505 \times 10^{10} \text{ Btu}$$

where

H_w = Thermal energy in Btus of the makeup water supplied to the HRI

h_w = Heating value of water in Btu/pound

M_{17} = Makeup water supplied to HRI in pounds

The following provides the computation for H_{hri}:

$$H_{hri} = (3.672 \times 10^{10} \text{ Btu}) + (1.362 \times 10^{8} \text{ Btu}) + (2.549 \times 10^{10} \text{ Btu}) + (0.021 \times 10^{10} \text{ Btu}) + (0.6852 \times 10^{10} \text{ Btu}) + (0.1505 \times 10^{10} \text{ Btu}) \quad (25)$$

$$= 7.04 \times 10^{10} \text{ Btus}$$

C. Long-term Cost-Effectiveness

The equations for long-term cost-effectiveness were taken directly from reference 1 and solved using the information from Appendix A.

Cost Equations — FY-81 Data Base

1. $$SOM = \frac{Mt_a \times 10^6}{M_{15} \times h_s} = \frac{10{,}686 \times 10^6}{(24{,}584{,}199)(1{,}187)} = 0.3662 \text{ man-hours}/10^6\text{Btus} \quad (26)$$

where

SOM = Specific Operating Man-hours

Mt_a = Man-hours of effort spent operating the HRI

M_{15} = Total amount of steam produced (pounds)

h_s = Heating value of the steam (Btu/pound)

Cost Equations (Continued) FY-81 Data Base

2. $$SRM = \frac{(Mt_b + Mt_c + Mt_e) \times 10^6}{M_{15} \times h_s} = \frac{314.5 \times 10^6}{2.918 \times 10^{10}} \quad (27)$$

$$= 0.1307 \text{ man-hours}/10^6\text{Btu}$$

where

SRM = Specific Repair and Maintenance Man-hours

Mt_b = Man-hours of effort spent in preventive maintenance

Mt_c = Man-hours of effort spent in corrective maintenance

Mt_e = Man-hours of effort spent on the HRI during idle non-operational downtime (equal to zero for FY-81)

M_{15} = Total amount of steam produced (pounds)

h_s = Heating value of the steam (Btu/pound)

3. $$STM = SOM + SRM = (0.1307 + 0.3662) \quad (28)$$

$$= 0.4969 \text{ man-hours}/10^6\text{Btu}$$

where

STM = Specific Total Man-hours

4. $$SRC = \frac{(CP)(10^6)}{M_{15} \times h_s} = \frac{\$25,743.12 \times 10^6}{2.918 \times 10^{10}} = \$0.88/10^6\text{Btu} \quad (29)$$

where

SRC = Specific Repair and Maintenance Cost

CP = Total cost of parts used in repairs/replacements and maintenance

M_{15} = Total amount of steam produced (pounds)

h_s = Heating value of steam (Btu/pound)

During FY-81, the cumulative cost for repair parts was \$25,743.12. One bill for the repair and redesign of the relief stack totaled \$12,000. There was no cost breakdown for labor or material. It was estimated that \$6000 was expended for labor and \$6000 for material. The \$6000 for material is part of the \$25,743.12.

5. $$SCC = \frac{(CF + CC)(10^6)}{M_{15} \times h_s} = \frac{\$95,873.24 \times 10^6}{2.918 \times 10^{10}} = \$3.28/10^6\,\text{Btu} \qquad (30)$$

where

SCC = Specific Consumable Costs

CF = Total cost of fuel used (virgin and waste oil, diesel and electrical power)

CC = Total cost of consumable supplies not included in CF

M_{15} = Total amount of steam produced (pounds)

h_s = Heating value of the steam (Btu/pound)

The breakdown in costs and quantities used for the one year operation is as follows:

(1) Water treatment chemicals

Salt	= (23,960 pounds)(\$2.60/80 pounds)	= \$ 779	(31)
PO_4	= (448 pounds)(\$50.64/100 pounds)	= \$ 227	(32)
SO_3	= (511.5 pounds)(\$29.36/100 pounds)	= \$ 140	(33)
	Subtotal	\$1156	

(2) Electrical power

1 KwH = 11,600 Btu
1 KwH = \$ 0.06

$$E_T = \frac{(0.6852 \times 10^6\ \text{Btu})(\$0.06/\text{KwH})}{(11,600\ \text{Btu/KwH})} = \$35,400 \qquad (34)$$

(3) Waste oil

188,851 gallons consumed @ \$0.30/gallon

cost for waste oil = (188,851 gallons)(\$0.30/gallon) = \$56,655 (35)

(4) Virgin oil

981 gallons consumed @ \$1.12/gallon

Cost for virgin oil = (981 gallons)(\$1.12/gallon) = \$1,099 (36)

(5) Diesel fuel

649 gallons consumed @ \$1.22/gallon

Cost for diesel fuel = (649 gallons)(\$1.22/gallon) = \$792 (37)

(6) Other consumables

Cost estimated at \$772

(7) Total

The cost total of (1) thru (6) is \$95,874

6. $$ACS = SRC + SCC + (STM \times W) = \$9.13/10^6 \text{ Btu} \quad (38)$$

where

ACS = Average Cost of Steam

SRC = Specific Repairs and Maintenance Cost

SCC = Specific Consumable Cost

STM = Specific Total Man-hours

W = Wages in dollars per hour (based on an estimate derived from public works job orders of \$10/hr.)

D. Long-term Solid Waste Disposal Efficiency

The efficiency of the HRI facility to reduce the volume of solid waste that would otherwise be delivered to the landfill and to produce steam will be determined by the following equations.

1. $$PR = \frac{M_{12}}{t_a} = \frac{(3750.28) - (174.005)}{3400} = 1.052 \text{ tons/hour} \quad (39)$$

where:

PR = Processing rate of the HRI facility in tons per hour

M_{12} = Solid waste burned in the HRI in tons

t_a = HRI operation time in hours

2. $$SP = \frac{M_{15}}{M_{12}} = \frac{24,584,199}{7,152,560} = 3.44 \quad (40)$$

where

SP = Efficiency of steam production, in pounds of steam per pound of solid waste

M_{12} = Solid waste supplied to HRI, in pounds

M_{15} = Steam produced, in pounds

3. $$DR = \frac{M_{12} - M_{14}}{M_{12}} = \frac{(7,152,560 - 1,893,720}{24,584,199} = 0.735 \quad (41)$$

where

DR = Efficiency of solid waste weight reduction through incineration.

M_{12} = Solid waste burned in the HRI, in pounds

M_{14} = Wet ash removed, in pounds

M_{15} = Steam produced, in pounds

In analyzing the long-term cost-effectiveness, the incineration process, and the production of steam were considered together. For FY-81, the total amount of solid waste delivered to the plant was 7,500,570 pounds. The total sent back to the landfill was 2,269,520 pounds. Therefore, the percentage of landfill reduction (PLR) for FY-81 was:

$$PLR = 100 \times \; 1 - \frac{(M_3 + M_{14} + M_a)}{M_3 + M_1} = 100 \times [1 - \frac{2,269,520}{7,500,570}] = 70\% \quad (42)$$

where

M_3 = Amount of solid waste rejected by hand, in tons

M_1 = Amount of solid waste incinerated, in tons

M_a = Amount of fly ash removed by the dust filter, in tons

M_{14} = Amount of wet ash removed, in tons

The amount of waste delivered to the HRI minus the amount of waste taken from the HRI provides an index for landfill savings accomplished by incineration. This number for FY-81 was 5,231,050 pounds or 2,615.5 tons.

E. Statistical Evaluation

The empirically derived MTBF value reported in Table 3 indicates that on the average the HRI operated 126 hours until failure during FY-81. Further chi-square statistical analysis utilizing chi-square distribution and "time to failure" data was performed to determine the lower one-sided 90 percent confidence limit.

Based on the FY-81 data and the assumption of an exponential distribution, the 90 percent confidence MTBF is 97 hours. Thus, there is a 90 percent probability that the same equipment operating under similar conditions would demonstrate an MTBF of 97 hours or better. It should be noted that all 27 reported failures were entered; including those which resulted in equipment modification.

Table 5 provides the distribution of the times to failure of the 27 failures that occurred during FY-81. The following discussion provides the details of this statistical evaluation.

Table 5. NS Mayport HRI Time To Failure

Equipment Time To Failure Data		
375.83	68.5	66.83
16.92	136.83	6.17
402.25	23.00	2.50
115.17	51.25	11.69
155.08	185.25	133.01
242.25	27.67	196.25
161.83	146.33	203.67
24.50	224.33	42.83
49.58	69.17	254.04

To estimate the lower one-sided confidence limit on the above observed, a chi-square distribution technique was applied. The following provides cursory discussion, equation and solution.

$$M_{L1} = \frac{2T}{x^2(\alpha,\ 2r + 2)}, \tag{43}$$

$$\frac{(2)\ (3400)}{x^2(.1,56)} = \frac{6800}{69.92} = 97.26 \text{ hours} \tag{44}$$

where

M_{L1} = Lower one-sided confidence limit on MTBF

x^2 = The α percent point of the chi-square distribution for (2r +2) degrees of freedom

r = The number of failures accumulated during testing

= The acceptable risk of error

$1-\alpha$ = Confidence level

T = Test duration (in this case 3400 hours)

(α = .1 because the calculation is based on a 90% Confidence level)

F. Time Categories

During the evaluation and extraction of data, manipulation of the reported time categories was required to provide the proper increments of time necessary to compute the various RAM parameters. This was particularly true during periods of downtime when both corrective and preventive (routine) maintenance was performed. The reported data did not always indicate when preventive or corrective maintenance started and stopped during long periods of shutdown. It was often implied that the entire day (i.e. 24 hours) was spent performing both corrective and preventive maintenance. The data from such scenarios were modified using the following criteria. It was estimated that 10 hours out of each 24-hour downtime cycle were spent on actual corrective maintenance (t_c) and the remaining 14 hours were logged under t_e, which indicates that the HRI is idle, but not operational. The resulting time categories are reflected in table A-1 (Appendix A). This technique provides a desired sensitivity to ensure more realistic RAM data.

During these lengthy shutdowns for corrective maintenance the three shifts performed preventive maintenance of the nature that was desirable, but not required. The logs showed that preventive maintenance was performed during these shutdown periods. To correctly solve the time equation for the HRI operation, given in reference 1 and listed below, the time categories cannot overlap. Therefore, when the system was shutdown for corrective maintenance and some preventive maintenance was performed concurrently, the time was charged only to corrective maintenance.

$$T = t_a + t_b + t_c + t_d + t_e = 8736 \text{ hours}$$

where:

- T - HRI monitoring period FY-81 = 364 days (8736 hours)
- t_a - Operating period, hours
- t_b - Calendar time spent on routine maintenance
- t_c - Calendar time spent on repairs/replacement
- t_d - Idle time, HRI operational (but not used)
- t_e - Idle time, HRI not operational

ACRONYM/NOMENCLATURE LIST

A_o	-	Operational availability (see equations 10-12)
CC	-	Total cost of consumable supplies not included in CF
CF	-	Total cost of fuel used (virgin and waste oil, diesel, and electrical power)
CMR	-	Corrective Maintenance Ratio (see equation 15)
CP	-	Total cost of parts used in repair, maintenance, and replacement
DR	-	Efficiency of solid waste weight reduction through incineration (see equation 41)
E_t	-	Electrical power in Btus supplied to the HRI (see equation 23)
e	-	Base of Naperian log system (2.718)
FY-81	-	Fiscal Year 1981 (29 September 80 through 30 September 81)
HRI	-	Heat Recovery Incinerator
H_f	-	Heat in Btus from fuel oil supplied to front-end loader (see equation 22)
H_{hri}	-	Btus supplied to HRI (see equations 18 through 25)
H_{sw}	-	Heat in Btus derived from solid waste and supplied to HRI (see equation 19)
H_{vo}	-	Heat in Btus derived from waste oil and supplied to HRI (see equation 20)
H_w	-	Thermal energy in Btus of the makeup water supplied to the HRI (see equation 24)
H_{wo}	-	Heat in Btus derived from waste oil and supplied to the HRI (see equation 21)
h_f	-	Heating value from fuel oil in Btu/pound
h_{sw}	-	Heating value from solid waste in Btu/pound
h_{vo}	-	Heating value from virgin oil in Btu/pound
h_w	-	Heating value of water in Btu/pound
h_{wo}	-	Heating value of waste oil in Btu/pound

ACRONYM/NOMENCLATURE LIST (Continued)

h_s	-	Average total heat of steam produced by the HRI, Btu/pound
M_1	-	Amount of solid waste arriving at the HRI facility, tons
M_3	-	Amount of solid waste that is hand-rejected, tons
M_{12}	-	Solid waste supplied to HRI, pounds (M_1 - M_3)
M_{13}	-	Amount of fuel and waste oil, pounds
M_{14}	-	Wet ash removed, pounds
M_{15}	-	Steam produced over the monitoring period, pounds
M_{17}	-	Makeup water supplied to HRI, pounds
M_{19}	-	Blowdown, pounds
M_{20}	-	Virgin oil supplied to HRI, pounds
M_{21}	-	Waste oil supplied to HRI, pounds
M_{22}	-	Fuel oil supplied to front-end loader, pounds
MI	-	Maintainability Index (see equation 6)
M_{L1}	-	Lower one-sided confidence limit on MTBF (see equation 43)
Mt_a	-	Man-hours of effort spent on the HRI during the period t_a
Mt_b	-	Man-hours of effort spent on the HRI during the period t_b
Mt_c	-	Man-hours of effort spent on the HRI during the period t_c
Mt_d	-	Man-hours of effort spent on the HRI during the period t_d
Mt_e	-	Man-hours of effort spent on the HRI during the period t_e
MTBF	-	Mean-Time-Between-Failures, hours (see equations 1 through 3)
$MTBF_{as}$	-	Mean-Time-Between-Failures, ash handling subsystem (see equation 2)
$MTBF_{bs}$	-	Mean-Time-Between-Failures, boiler subsystem (see equation 3)
$MTBF_{hri}$	-	Mean-Time-Between-Failures, heat recovery incinerator (see equation 1)
$MTBF_{ht}$	-	Mean-Time-Between-Failures, heat transfer network

ACRONYM/NOMENCLATURE LIST (Continued)

$MTBF_{is}$	-	Mean-Time-Between-Failures, incinerator subsystem
$MTBF_{ps}$	-	Mean-Time-Between-Failures, processing subsystem
$MTBF_{rs}$	-	Mean-Time-Between-Failures, receiving subsystem
MTTR	-	Mean-Time-to-Repair, hours (see equation 7)
MTBMA	-	Mean-Time-Between-Maintenance Action, hours (see equations 4-6)
NAS	-	Naval Air Station
NCEL	-	Naval Civil Engineering Laboratory
N_f	-	Number of failures that caused shutdown of the HRI or subsystem
N_{ma}	-	Number of maintenance actions
N_r	-	Number of repairs
NS	-	Naval Station
PC	-	Processing capacity of the HRI facility in tons per hour (see equation 25)
PLR	-	Percent Landfill reduction (by weight) for solid waste accepted at HRI.
PMR	-	Preventive Maintenance Ratio (see equation 4)
R	-	Reliability as a probability (expressed as a decimal)
RAM	-	Reliability, Availability, and Maintainability
RCRA	-	Resource Conservation Recovery Act
Rp	-	Total active repair time spent on corrective maintenance
SCC	-	Specific Consumable Costs (see equation 30)
SOM	-	Specific Operating Man-hours (see equation 26)
SP	-	Efficiencies of steam production in terms of pounds of steam per pounds of solid waste (see equation 40)
SRM	-	Specific Repairs and Maintenance Man-hours (see equation 27)
STM	-	Specific Total Man-hours (see equation 28)

ACRONYM/NOMENCLATURE LIST (Continued)

T	-	Total monitoring period, hours
T_{kwh}	-	Total kilowatt hours supplied to the HRI
T_E	-	Overall thermal efficiency (see equation 17)
t_a	-	HRI operating period, hours
t_b	-	Time spent in routine maintenance, can be calendar or total time, hours
t_c	-	Time spent in repairs/replacements, can be calendar or total time, hours
t_d	-	HRI idle time (operational), hours
t_e	-	HRI idle time (not operational), hours
t_m	-	Mission time for Reliability calculations, hours
W	-	Wages in dollars per hour

APPENDIX A

WEEKLY SUMMARIES OF

NS MAYPORT HRI DATA

TABLE A-1. BREAKDOWN OF HOURS

*	DATE	t_a	t_b	t_c	t_d	t_e		DATE	t_a	t_b	t_c	t_d	t_e
1	10/5	93.33	5.50	0.00	65.17	4.00	27	4/6	76.25			00.0	0.00
2	10/12	108.75	7.00	0.00	48.25	4.00	28	4/13	18.67	0.00	65.00	21.00	154.80
3	10/19	84.83	23.00	0.00	56.17	4.00	29	4/20	59.58	6.00	8.00	82.42	12.00
4	10/26	88.92			0.00		30	4/27	107.00	0.00	0.00	57.00	4.00
5	11/2	0.00			0.00		31	5/4	100.67	6.00	0.00	57.33	4.00
6	11/9	0.00			0.00		32	5/11	99.50	6.00	0.00	58.50	4.00
7	11/16	0.00	0.00	186.00	75.08	322.00	33	5/18	84.17	0.00	11.17	52.41	20.25
8	11/23	0.00	0.00	50.00	0.00	118.00	34	5/25	NA			0.00	
9	11/30	0.00	0.00	60.00	0.00	107.50	35	6/1	NA			0.00	
10	12/7	107.75	6.00	16.00	34.25	4.00	36	6/8	NA			0.00	
11	12/14	113.50	0.00	0.00	50.50	4.00	37	6/15	66.92	0.00	202.00	0.58	402.50
12	12/21	88.33	12.42	0.00	63.25	4.00	38	6/22	6.17	0.00	33.50	39.33	89.00
13	12/28	0.00	104.00	0.00	60.00	4.00	39	6/29	2.50	0.00	50.00	9.08	106.42
14	1/4	92.67	0.00	3.00	68.33	4.00	40	7/6	79.75	0.00	10.00	71.42	6.83
15	1/11	155.50	0.00	0.00	8.50	4.00	41	7/13	107.42	5.50	1.08	50.00	4.00
16	1/18	112.00	12.00	0.00	40.00	4.00	42	7/20	23.42	136.00	0.00	2.58	6.00
17	1/25	36.92	19.00	21.00	18.08	73.00	43	7/27	0.00	168.00	0.00	0.00	0.00
18	2/1	111.75	0.00	0.00	52.25	4.00	44	8/3	0.00	106.25	5.75	52.00	4.00
19	2/8	91.00	6.00	0.00	1.00	70.00	45	8/10	100.67	6.50	0.00	56.83	4.00
20	2/15	0.00	0.00	39.00	33.00	96.00	46	8/17	97.58	0.00	19.35	9.67	41.40
21	2/22	93.75	0.00	0.00	70.25	4.00	47	8/24	96.50	6.00	0.00	61.50	4.00
22	3/2	100.83	6.00	0.00	57.17	4.00	48	8/31	91.00	8.00	0.00	0.50	68.50
23	3/9	86.83	6.00	15.50	55.67	4.00	49	9/7	46.50	0.00	1.08	0.67	119.75
24	3/16	111.25	6.00	0.00	46.75	4.00	50	9/14	68.37	34.00	8.25	21.38	36.00
25	3/23	103.83	3.00	14.00	12.17	35.00	51	9/21	109.25	34.00	0.00	20.75	4.00
26	3/30	109.00	0.00	0.00	55.00	4.00	52	9/28	66.83	9.00	0.00	88.17	4.00

LEGEND:

* Date given is the date of the last day of the week (Sunday) for the interval considered.

Indicates summation over the number of intervals it runs through

t_a - hours of operation

t_b - hours spent on routine maintenance

t_c - hours spent on corrective maintenance

t_d - hours HRI is idle, but operational

t_e - hours HRI is idle, but not operational

TOTALS:

t_a = 3399.46 hours

t_b = 747.17 hours

t_c = 820.68 hours

t_d = 1783.97 hours

t_e = 1984.95 hours

TABLE A-2. BREAKDOWN OF MAN-HOURS

	*DATE	Mt_a	Mt_b	Mt_c		*DATE	Mt_a	Mt_b	Mt_c
1	10/5	320	4.5	0	27	4/6	230	0	0
2	10/12	320	7	0	28	4/13	128	105	12
3	10/19	320	62	0	29	4/20	212	11	15
4	10/26	360			30	4/27	240	0	9
5	11/2	0			31	5/4	214	11	0
6	11/9	0			32	5/11	214	11	0
7	11/16	0	222	390	33	5/18	470		
8	11/23	360	0	35.5	34	5/25	0		
9	11/30	0	48	125	35	6/1	0		
10	12/7	360	12	0	36	6/8	0		
11	12/14	360	0	0	37	6/15	272	1054	106
12	12/21	360	38	0	38	6/22	80	48	51
13	12/28	0	100	0	39	6/29	7	96	24
14	1/4	360	0	6	40	7/6	273	0	24
15	1/11	360	0	0	41	7/13	282.6	11	0
16	1/18	360		0	42	7/20	88		0
17	1/25		100	102	43	7/27	0		0
18	2/1	421	0	0	44	8/3	0	300	10
19	2/8	270	11	0	45	8/10	320	11	0
20	2/15	0	20	232	46	8/17	320	11	8.5
21	2/22	244	11	0	47	8/24	320	11	0
22	3/2	412	11	0	48	8/31	320	144	0
23	3/9	273	11	45.5	49	9/17	140	0	3
24	3/16	290	11	0	50	9/14	256	43	16
25	3/23	320	11	13	51	9/21	320	27	0
26	3/30	320	0	0	52	9/28	320	13	0

LEGEND:

* Date given is the date of the last day of the week (Sunday) for the interval considered

Indicates summation over the number of intervals it runs through.

Mt_a - man-hours spent in operation

Mt_b - man-hours spent on routine maintenance

Mt_c - man-hours spent on corrective maintenance

TOTALS:

Mt_a = 10,686 man-hours

Mt_b = 2586.5 man-hours

Mt_c = 1228 man-hours

TABLE A-3. BREAKDOWN OF WEEKLY CONSUMPTION
(MEASURED IN GALLONS)

	*DATE	M_{13}	M_{17}	M_{19}	M_1		*DATE	M_{13}	M_{17}	M_{19}	M_1
1	10/5	6263	NA	NA	110.98	27	4/6	4360	97,000	20,639	95.77
2	10/12	2365	NA	NA	104.24	28	4/13	563	10,000	2,955	18.19
3	10/19	4522	NA	NA	98.36	29	4/20	560	72,100	12,256	68.39
4	10/26	6724	NA	NA	72.10	30	4/27	7240	107,800	27,233	58.98
5	11/2	NA	NA	NA	NA	31	5/4	5174	112,300	29,508	106.66
6	11/9	NA	NA	NA	NA	32	5/11	4233	105,400	27,457	120.41
7	11/16	NA	NA	NA	NA	33	5/18	3985	82,700	27,125	96.50
8	11/23	7661	83,800	15,443	NA	34	5/25	NA	NA	NA	NA
9	11/30	NA	NA	NA	NA	35	6/1	NA	NA	NA	NA
10	12/7	4722	90,200	21,051	78.80	36	6/8	NA	NA	NA	NA
11	12/14	6867	134,500	21,541	96.56	37	6/15	3702	61,500	19,222	45.82
12	12/21	6273	121,800	23,038	82.34	38	6/22	2106	29,700	7,384	15.90
13	12/28	NA	NA	NA	NA	39	6/29	111	700	741	0.00
14	1/4	6565	125,900	23,391	110.57	40	7/6	2845	67,900	22,812	80.14
15	1/11					41	7/13	3599	96,800	20,305	149.25
16	1/18	15,974	352,900	69,136	290.81	42	7/20	1265	20,200	4,537	23.72
17	1/25	313	14,800	4,978	3.26	43	7/27	NA	NA	NA	NA
18	2/1	8107	180,800	28,536	155.26	44	8/3	NA	NA	NA	NA
19	2/8	6210	111,200	20,660	73.05	45	8/10	4979	92,000	19,648	86.59
20	2/15	NA	NA	NA	NA	46	8/17	4153	103,400	23,381	131.75
21	2/22	5621	117,700	16,391	90.10	47	8/24	3225	92,300	26,625	127.75
22	3/2	7009	142,000	27,728	100.60	48	8/31	5026	80,200	30,290	66.24
23	3/9	5348	110,900	23,367	112.66	49	9/7	1781	46,000	11,146	56.52
24	3/16	6643	140,500	28,526	110.68	50	9/14	2484	83,800	15,753	103.26
25	3/23	6055	423,300	23,800	98.24	51	9/21	44.10	105,000	22,874	124.93
26	3/30	7712	133,900	84,504	116.31	52	9/28	3077	93,500	14,601	94.59

LEGEND:

* Date given is the date of the last day of the week (Sunday) for the interval considered.

Indicates a summation over number of intervals it runs through

M_{13} - auxiliary fuel, gallons

M_{17} - makeup water, gallons

M_{19} - blowdown, gallons

M_1 - solid waste delivered to facility, tons

TOTALS:

M_{13} = 189,832 gallons of fuel and waste oil

M_{17} = 3,778,500 gallons of makeup water

M_{19} = 905,879 gallons of blowdown

M_1 = 3576.28 tons of solid waste incinerated

TABLE A-4. WEEKLY SOLID WASTE REJECTED ASH, AND STEAM OUTPUTS
(MEASURED IN POUNDS)

	*DATE	M_3	M_{14}	M_a	M_{15}		*DATE	M_{13}	M_{14}	M_a	M_{15}
1	10/5	10,330	44,600	80	NA	27	4/6	8,720	61,540	400	632,269
2	10/12	3,260	47,380	80	NA	28	4/13	NA	NA	NA	58,339
3	10/19	2,430	34,620	40	NA	29	4/20	NA	46,640	NA	495,508
4	10/26	5,940	46,300	30	NA	30	4/27	6,420	42,140	1,320	667,095
5	11/2	NA	NA	NA	NA	31	5/4	7,340	66,740	200	685,518
6	11/9	NA	NA	NA	NA	32	5/11	10,280	64,580	1,800	645,368
7	11/16	NA	NA	NA	NA	33	5/18	5,720	69,660	1,600	460,161
8	11/23	4,980	11,480	0	565,996	34	5/25	NA	NA	NA	NA
9	11/30	NA	NA	NA	NA	35	6/1	NA	NA	NA	NA
10	12/27	4,010	17,060	0	572,562	36	6/8	NA	NA	NA	NA
11	12/14	8,040	35,850	0	935,300	37	6/15	8,700	23,120	NA	350,062
12	12/21	8,200	55,260	0	817,749	38	6/22	NA	10,080	660	184,776
13	12/28	NA	NA	NA	NA	39	6/29	0	0	0	NA
14	1/4	4,020	21,940	0	848,775	40	7/6	15,140	42,800	NA	373,329
15	1/11					41	7/13	7,120	71,900	550	616,819
16	1/18	22,500	201,480	40	2,349,566	42	7/20	9,240	12,320	0	129,690
17	1/25	NA	NA	NA	81,326	43	7/27	NA	NA	NA	NA
18	2/1	15,440	103,010	440	1,260,746	44	8/3	NA	NA	NA	NA
19	2/8	47,020	47,020	2,040	749,000	45	8/10	12,780	NA	NA	599,075
20	2/15	NA	NA	NA	NA	46	8/17	14,580	60,440	900	662,557
21	2/22	15,060	54,700	6,080	838,839	47	8/24	16,660	92,160	600	543,789
22	3/2		70,540	200	946,172	48	8/31	7,240	38,800	1,720	413,255
23	3/9	6,200	46,020	180	724,773	49	9/7	NA	22,340	1,050	NA
24	3/16	9,040	53,520		927,145	50	9/14	7,280	46,340	1,240	563,429
25	3/23	10,760	66,540	800	3,307,860	51	9/21	9,820	57,080	780	680,003
26	3/30	15,520	63,200	4,180	408,999	52	9/28	8220	44,520	780	487,684

LEGEND:

* Date recorded is the date of the last day of the week (Sunday) for the interval considered.

Indicates summation over number of intervals it runs through.

M_3 - rejected solid waste, pounds

M_{14} - wet ash, pounds

M_a - fly ash, pounds

M_{15} - steam produced, pounds

TOTALS: (for the FY-81)

M_3 = 348,010 pounds rejected solid waste

M_{14} = 1,893,720 pounds of wet ash

M_a = 27,790 pounds of fly ash

M_{15} = 24,584,199 pounds of steam produced

M_{15} (calculation)

$M_{15} = (M_{17} \times e_{17}) - (M_{19} \times e_{19})$

where

M_{17} - Makeup water gallons

M_{19} - Blowdown water, gallons

e_{17} - Density of makeup water, pounds/gallons

e_{19} - Density of blowdown water, pounds/gallons

APPENDIX B

SUMMARY OF NS MAYPORT

HRI FAILURES/MAINTENANCE ACTIONS

This appendix contains a composite listing of the failures and maintenance actions reported during FY-81. They are listed in two sections: shutdown-related, and not related to shutdown. Each section is divided into four equipment group categories; boiler equipment failures, incinerator-equipment failures, ash removal equipment failures, and front-end processing-equipment failures. Each failure is listed in its appropriate section and category. The weekly time interval in which the failure occurred is provided in parenthesis.

I. HRI Shutdown-Related Failures

The failures causing shut-down are listed below. The repetitive failures during the year were the broken shear pins, the ash conveyor and ram feed problems.

A. Boiler Equipment Failures

1. Hand hold plug (17)
2. Drain piping (19)
3. Blowdown valves (25)
4. Boiler tubes (42)
5. Deaerator tank (48)

B. Incinerator Equipment Failures

1. Relief stack door (4)
2. Relief stack refactory (8)
3. Hydraulic pump (23)
4. Stoker (27)
5. ID fan (38)
6. Damper motor #3 (39)

C. Ash Removal Equipment Failures

1. Chain off sprocket and broken shear pin (13)
2. Chain off sprocket, 4 broken shear pins, and 2 drive belts (28)
3. End plate on flight bar (39)

D. Receiving and Incinerator Feed Equipment Failures

1. Shaft seals and "O" rings in ram (7)
2. Ram rod packing on #1 cylinder (37)
3. Ram rod packing on #2 cylinder (49)
4. Overhead Crane (receiver board) (30)
5. Hydraulic ram seal packing (32)

II. Failures and Maintenance Actions Not Resulting in Shutdown

Failures and maintenance actions not resulting in shutdown are listed below. It is noted that failures C-7, C-8, C-9, D-2, and D-4 through D-7 are actual failures of the equipment and in these cases, waste and/or fuel oil was utilized to continue the heating process to generate steam.

A. Boiler Equipment Failure

1. Boiler tubes (slag build-up) (16)

B. Incerator Equipment

1. Tuyeres and tuyere shoes (16)
2. Cooler on hydraulic pump (23)

C. Receiving and Incinerator Feed Equipment Failures

1. Ram feeder (stuck) (1)
2. Ram feeder (stuck) (3)
3. Ram feeder (stuck) (3)
4. Ram feeder (stuck) (3)
5. Ram feeder ("O" ring) (9)
6. Front-end loader (oil leak) (15)
7. Overhead crane (hinge pin in clutch assembly, (18)
8. Overhead crane (out of calibration) (25)
9. Overhead crane (trolly wheels and receiver board) (33)

D. Ash Removal Equipment Failures

1. Conveyor off of sprocket (1)
2. Debris jammed gear and broke shear pin (14)
3. Chain off sprockets due to large chunk of metal caught under flight bar (17)
4. Chain off of sprocket, broken shear pin (22)
5. 4 flight bars and 2 shear pins broken (22)
6. Conveyor drive belt broke (25)
7. Chain off sprocket, broken drive belt, bent flight bars (46)

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